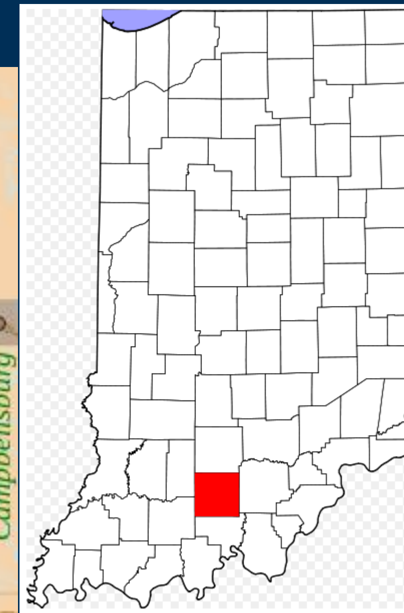
An Indiana Silver Jackets Project to Develop a Hydrologic-Response Model for Flood Mitigation in Orange County

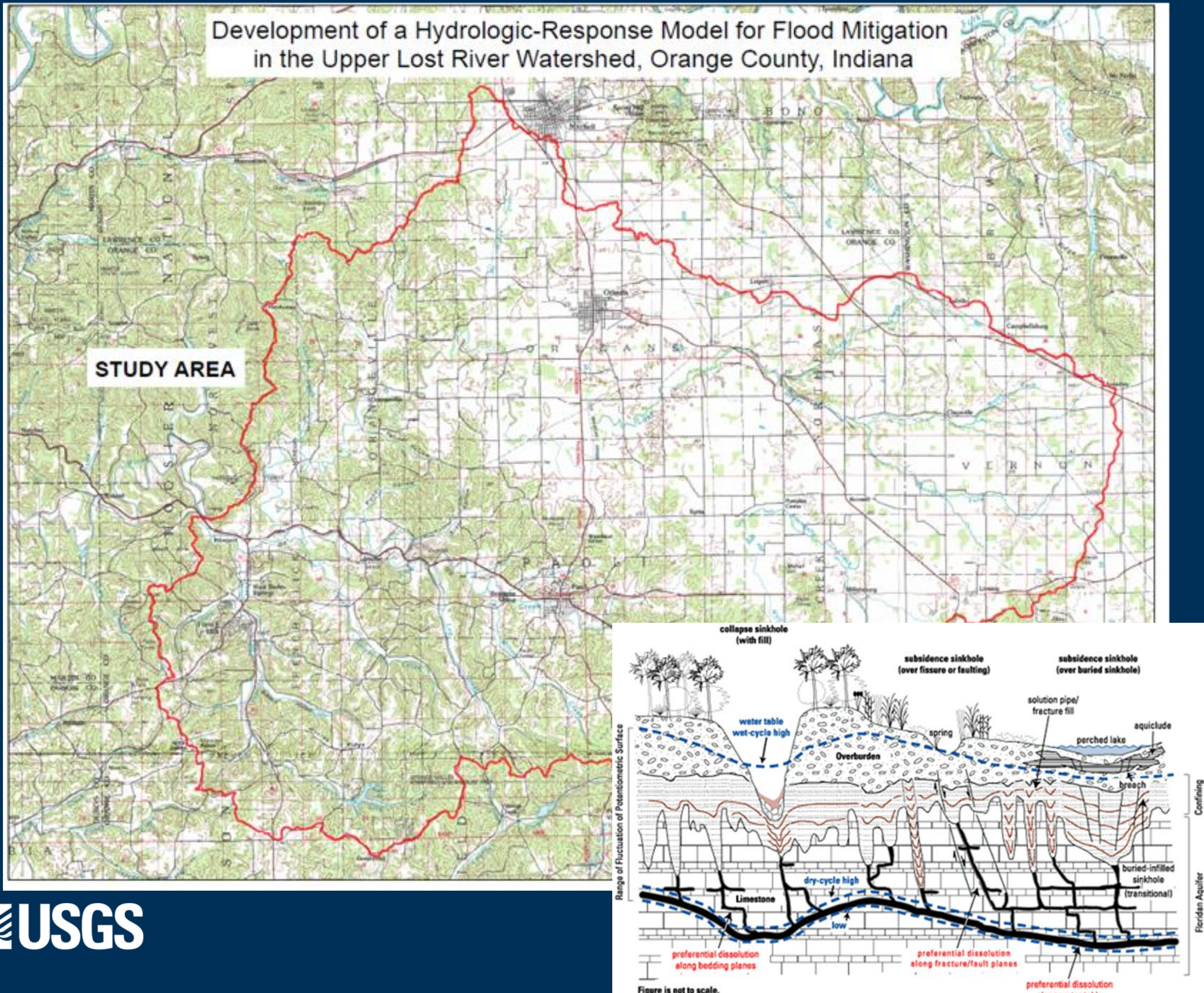
U.S. Department of the Interior
U.S. Geological Survey


Mitchell
Lawrence County
50
60
Martin County
Saltillo
Orleans
Leipsic
Orangeville
Northwest
Orangeville
Orleans
Northeast
150
337
Washington County
Campbellsburg
Prospect
Woodlawn Grove
West Baden Springs
French Lick
Paoli
56
Livonia
Stampers Creek
Paoli
French Lick
Chambersburg
Hardinsburg
145
Dubois County
Jackson
Greenfield
Southeast
Valeene
Patoka Lake
Map of
Orange County,
Indiana, USA



USGS

Development of a Hydrologic-Response Model for Flood Mitigation in the Upper Lost River Watershed, Orange County, Indiana



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Partners

Funding

Coordination

- Orange County
- West Baden Springs
- French Lick

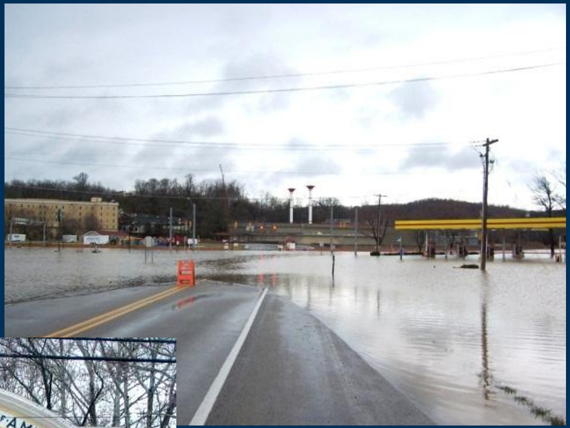
Monitoring Network

Team effort -

- Randy Bayless (USGS IN WSC - lead author),
- Chuck Taylor (KY Geological Survey - study design),
- Greg McCombs, (USGS KY WSC – field-data leader),
- USGS IN WSC data section (field operations),
- Randy Ulery (USGS KY WSC - WATER-TOPMODEL programmer),
- Pete Cinotto (USGS KY WSC - data compilation and analysis, editing)
- Moon Kim and Hugh Nelson (INKY WSC – GIS and data processing)

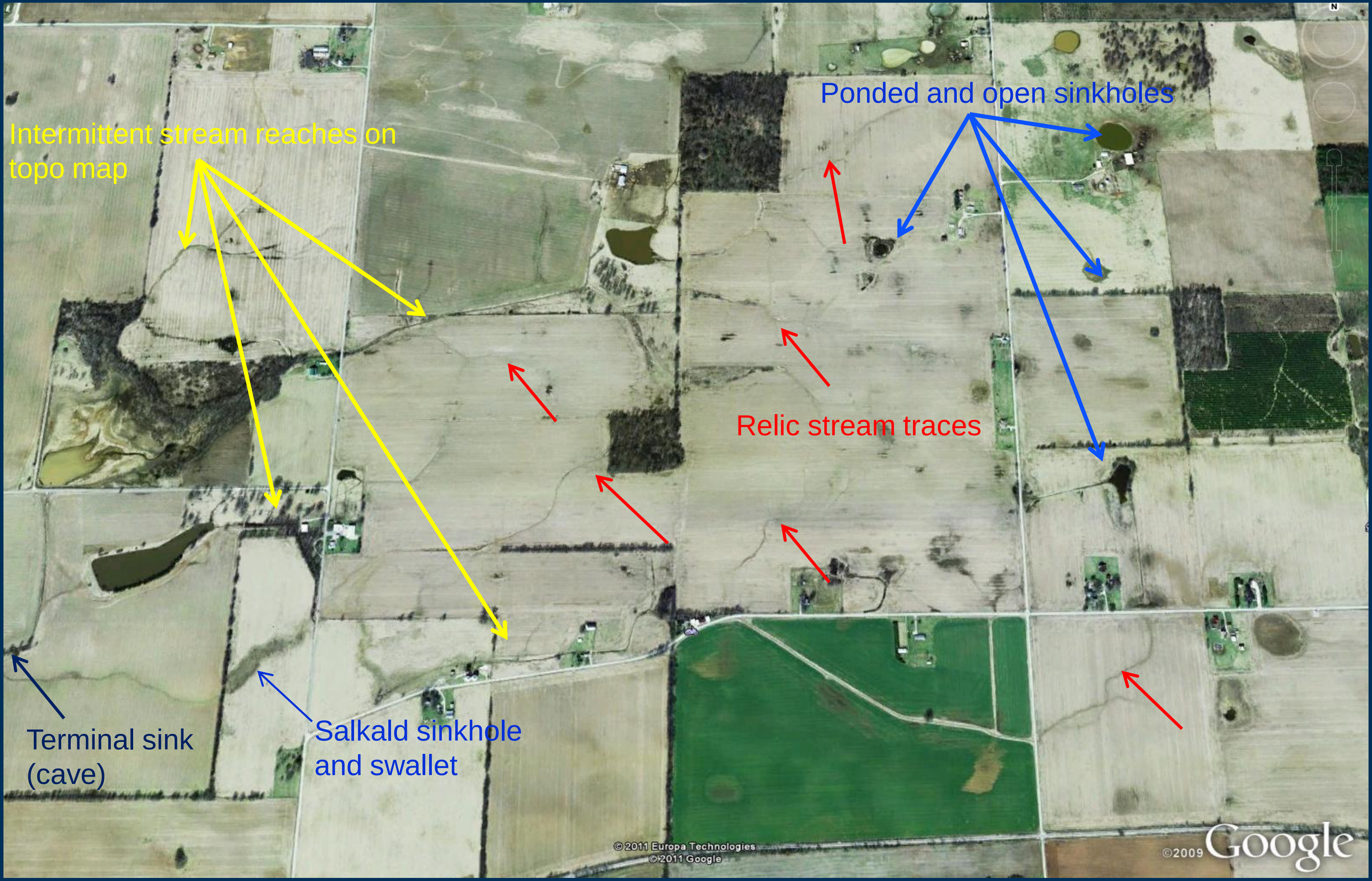
The Problem: Frequent Severe Flooding in Orange County, Indiana

- **Over the last two decades, much of Ohio River basin, including Orange County in south-central Indiana, has suffered repeated economically ruinous flooding.**
- **Recent major floods occurring in Lost River basin in September 22-23, 2006, March 12-22, 2008, June 7-9, 2008, and late March-early April, 2011 severely impacted the towns of French Lick, West Baden Springs, and Orleans, Indiana.**



Flooding in Orleans, Indiana, 2008 & 2011

Source of Orleans flooding:
Flood Creek blind valley or karst paleovalley



Flood Creek karst paleovalley

We can see this relic stream drainage pattern with GIS; these were lost to subsurface piracy into the Orangeville Rise conduit system.

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Source: Taylor and Nelson, 2008

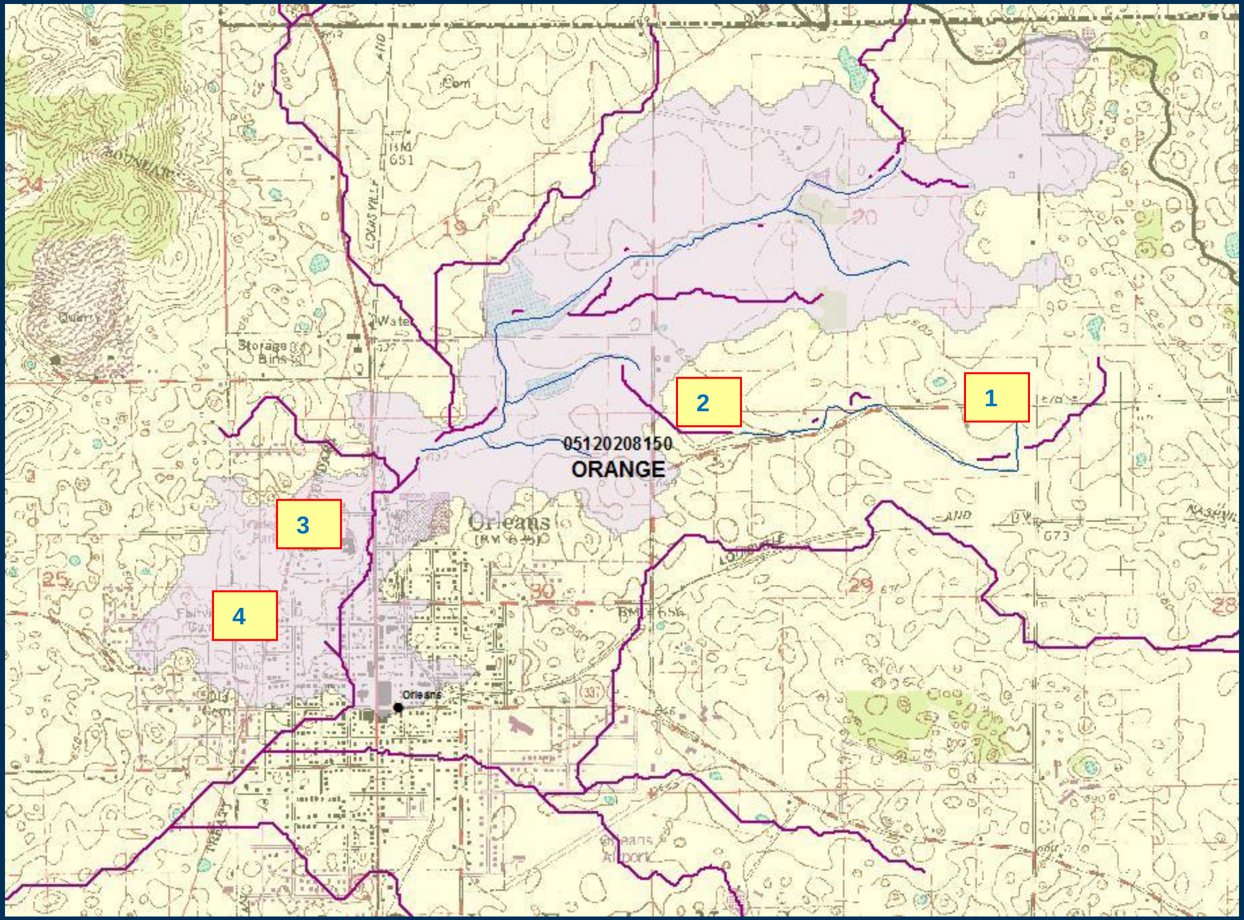
Re-Activation of former Flood Creek surface flows during high-flow events—Orleans 1993 Flood

1

2

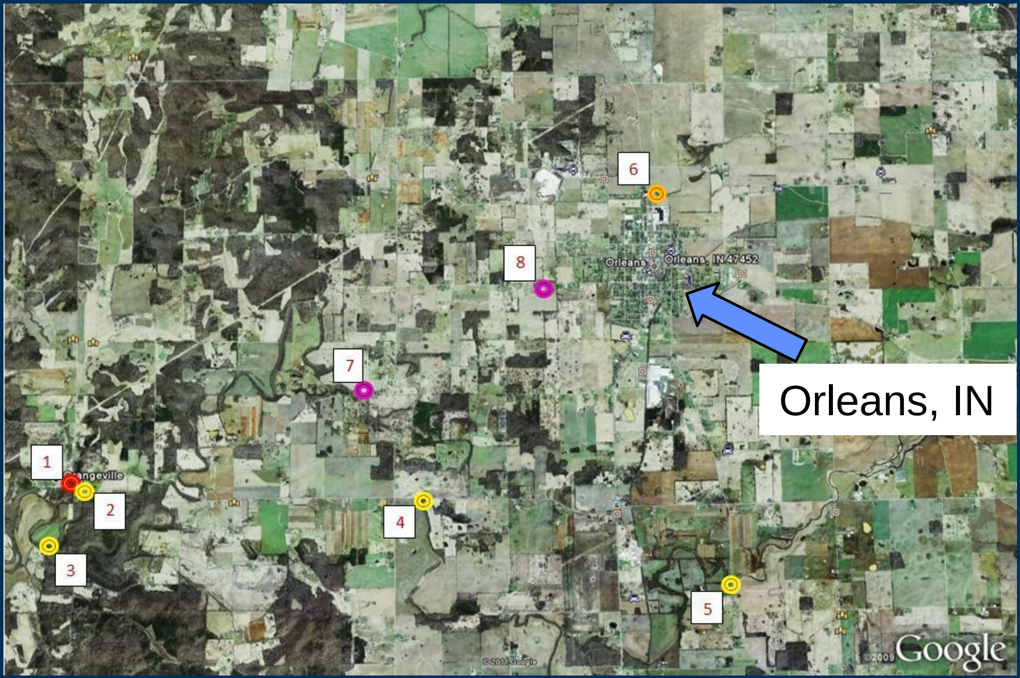
3

4



Given this, USGS established a network for monitoring the area
(slide from Taylor, June 2012)

- GOALS:
- Monitors drainage (surface flows) at critical locations within the karst terrain in the Orangeville-Orleans area.
- Focuses on characterizing the hydrology of Flood Creek sub-basin, northeast of Orleans, Indiana, including the relationship to the outlet spring (Orangeville Rise).
- Obtains data about timing and magnitude of storm flows in dry bed of Lost River.
- Tracks fluctuations in groundwater levels that may contribute to high-flow and flood conditions.



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What did this data tell us?

First – we’re only looking at a relatively small amount of data, but this can still tell us a few things…

We begin with a general evaluation of the Orangeville Rise USGS Streamflow-gaging station data – gage data is really useful, so you always start there (when you can) and then tie it all together.

Real-time Stage-Discharge Monitoring Station at Orangeville Rise at Orangeville, Indiana (03373550)

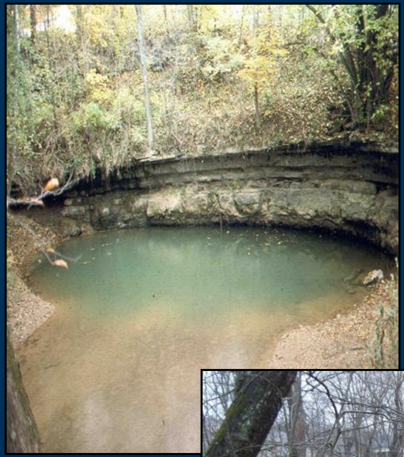
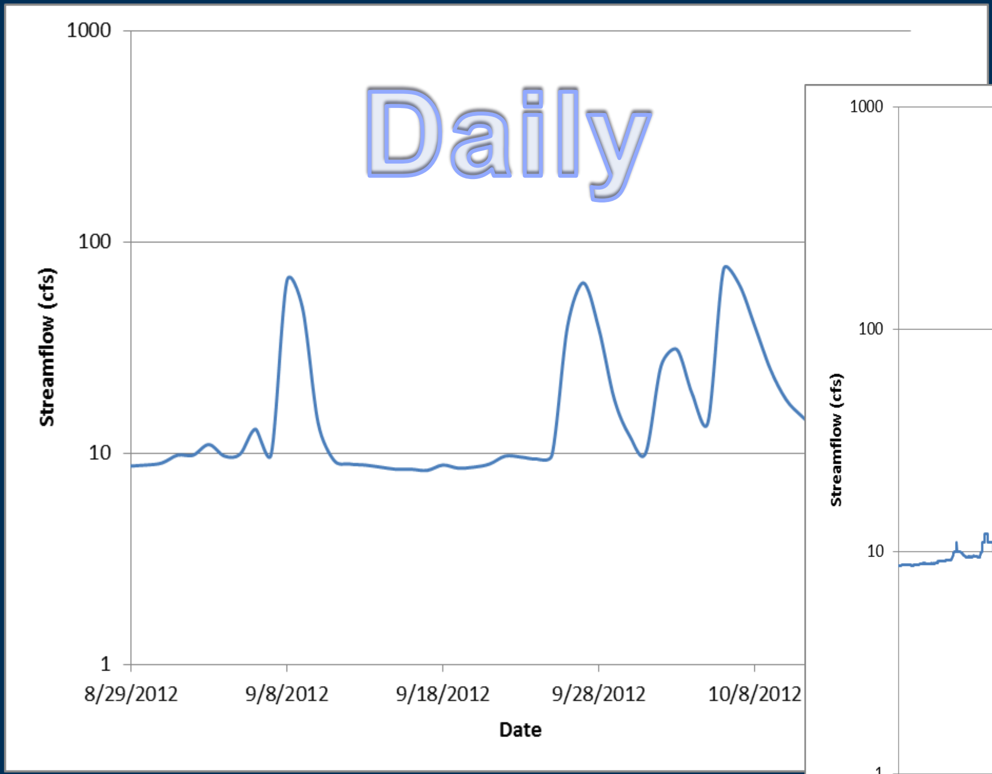
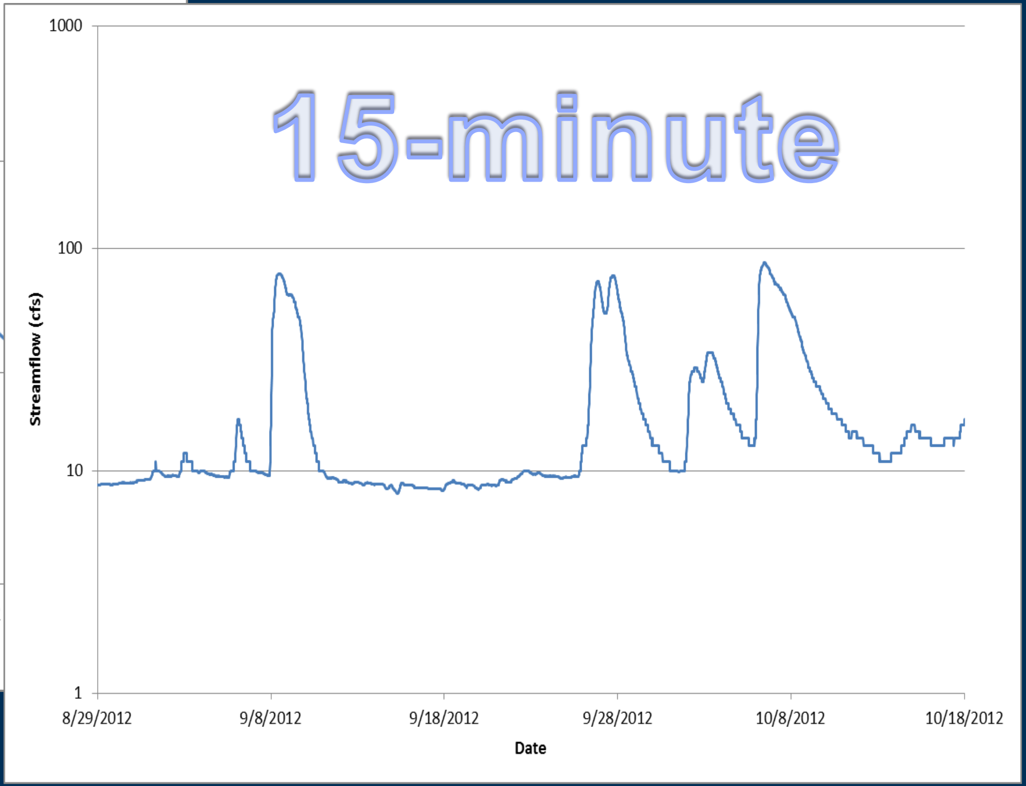


Photo: Ginger Korinek IN DNR

Orangeville Rise—artesian spring; 2nd largest spring in Indiana.

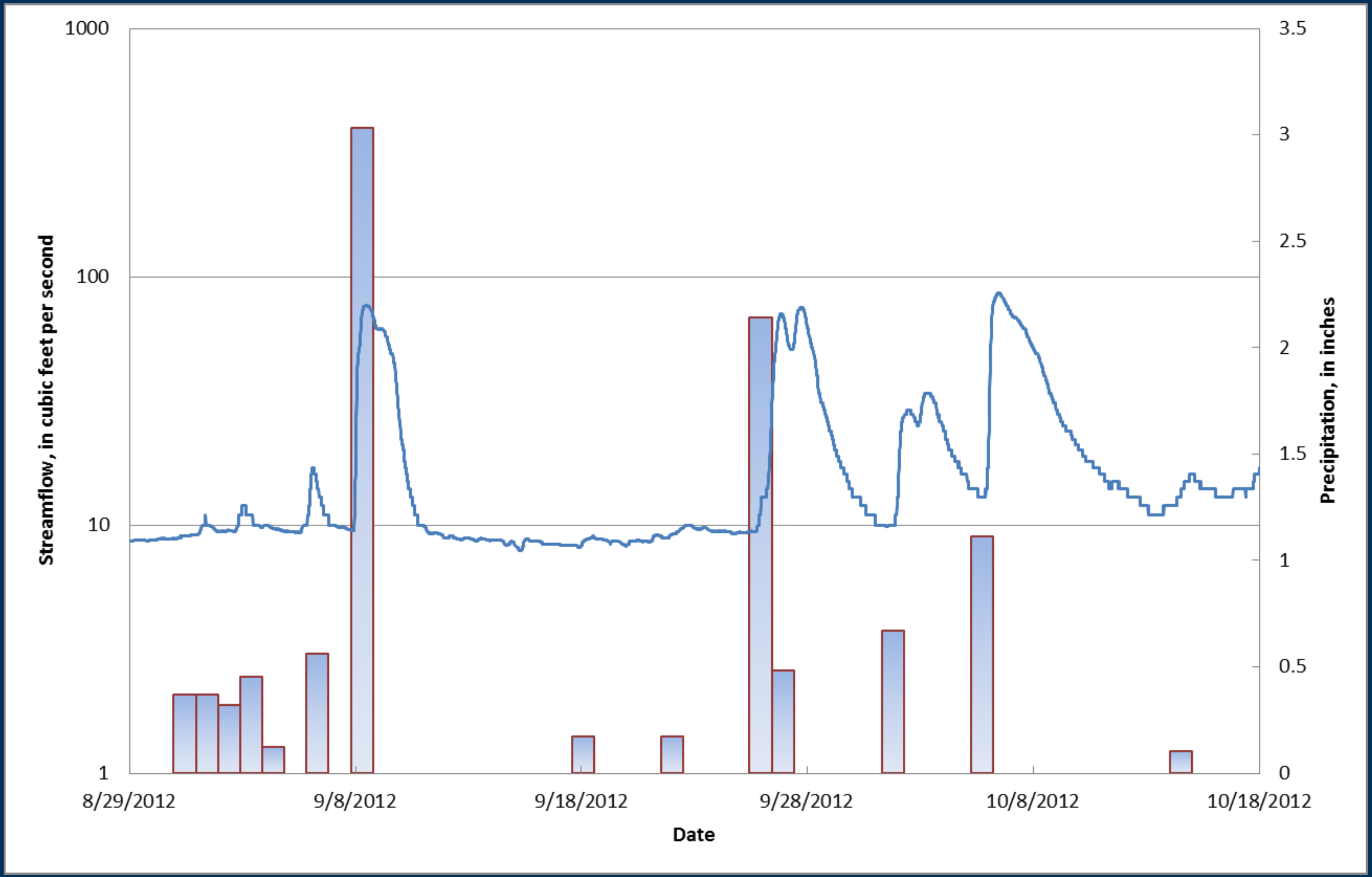
Higher-resolution data from a gage can tell us something about basin response and flooding…





Streamflow data for Orangeville Rise at Orangeville, Indiana (03373550) showing "double" storm peaks – possibly different TOC from contributing basins (Murdock and Powell (1968) and(or) result of "quick-flow" and "slow-flow" karst components – regardless, it results in some "spreading out" of the discharge (smaller peaks – longer duration).

Higher-resolution data tells us something about basin response and flooding…

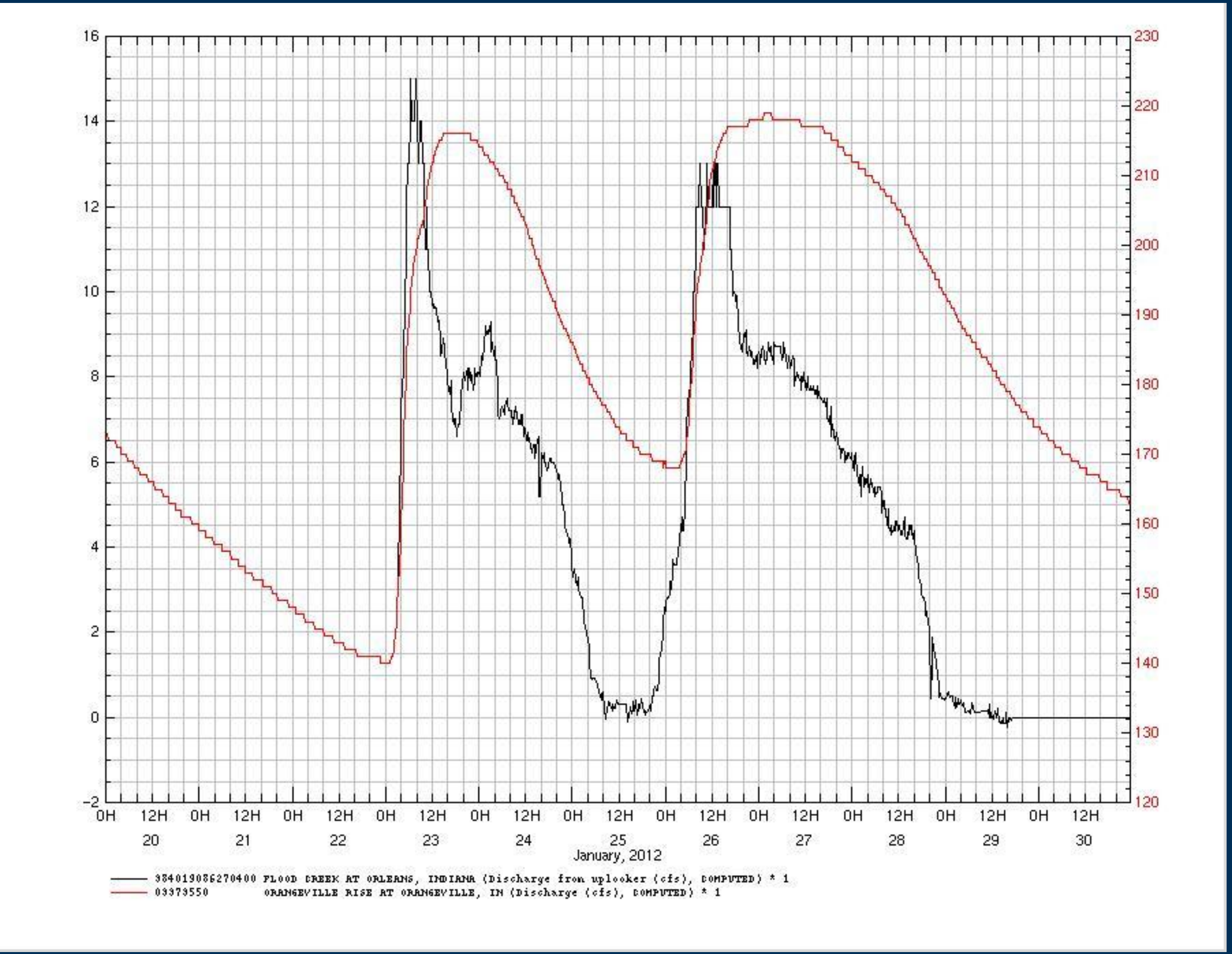


Next we tease out the details – how might it all fit together?

Evidence… Orangeville Rise and Flood Creek Discharge Hydrographs

Early hydrograph data was quickly showing an interesting relation between Flood Creek and Orangeville Rise.

- Responses are nicely in phase during this period (Jan 22-27). Flood Cr. peaks about 14 hours prior to Orangeville Rise.
- Flood Cr. peak discharge accounts for about 6-7% of Orangeville Rise discharge during this storm.



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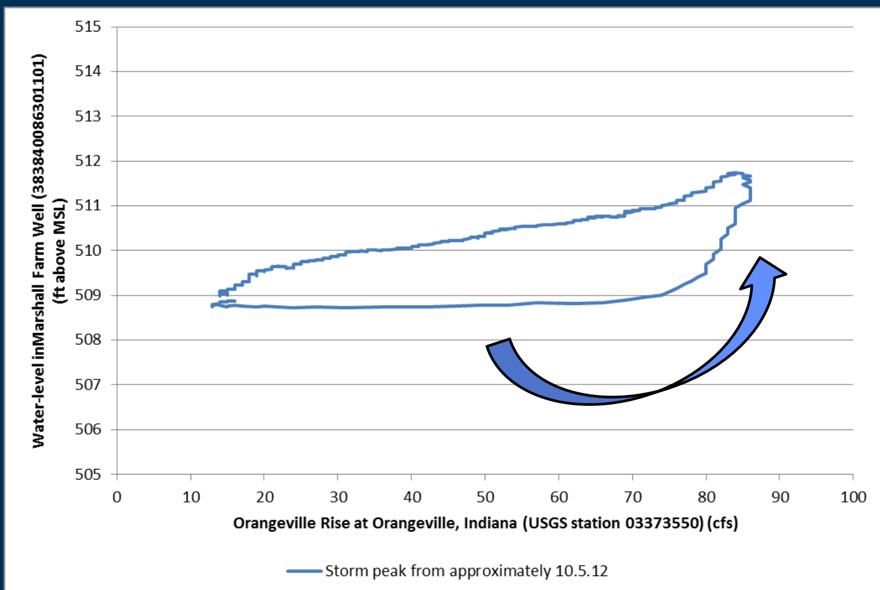
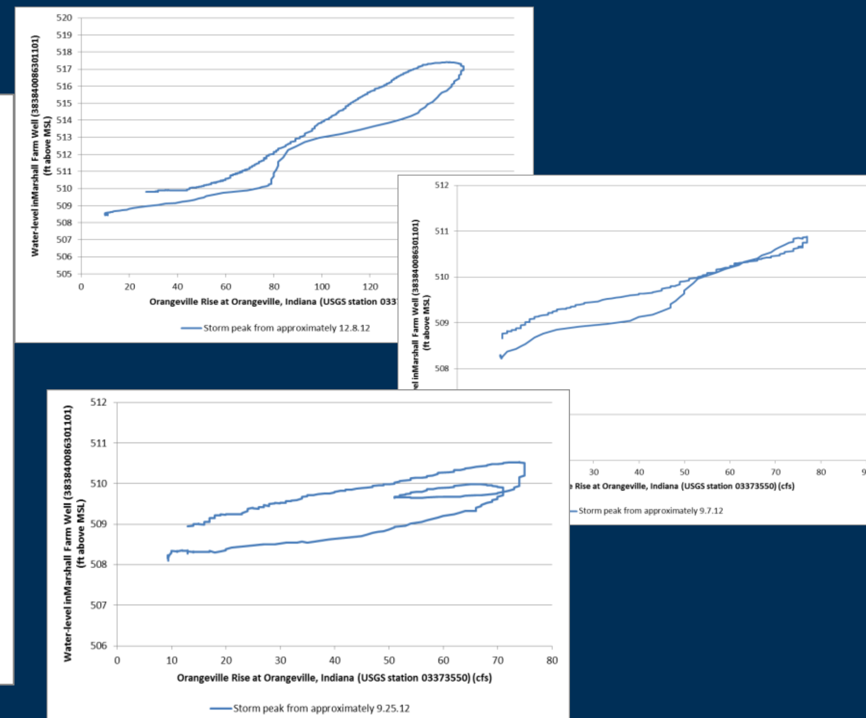
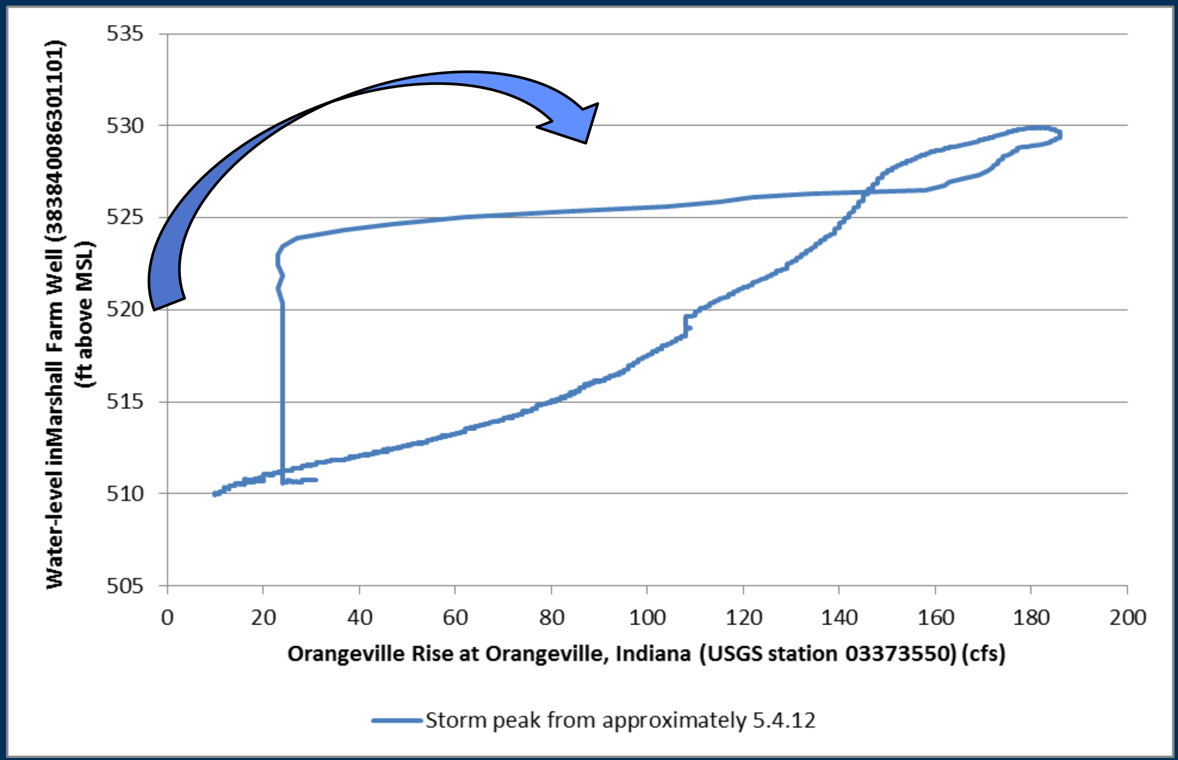
Lets then look at the relationship between ground-water levels (conduit in this case) and storm peaks at the Orangeville Rise…





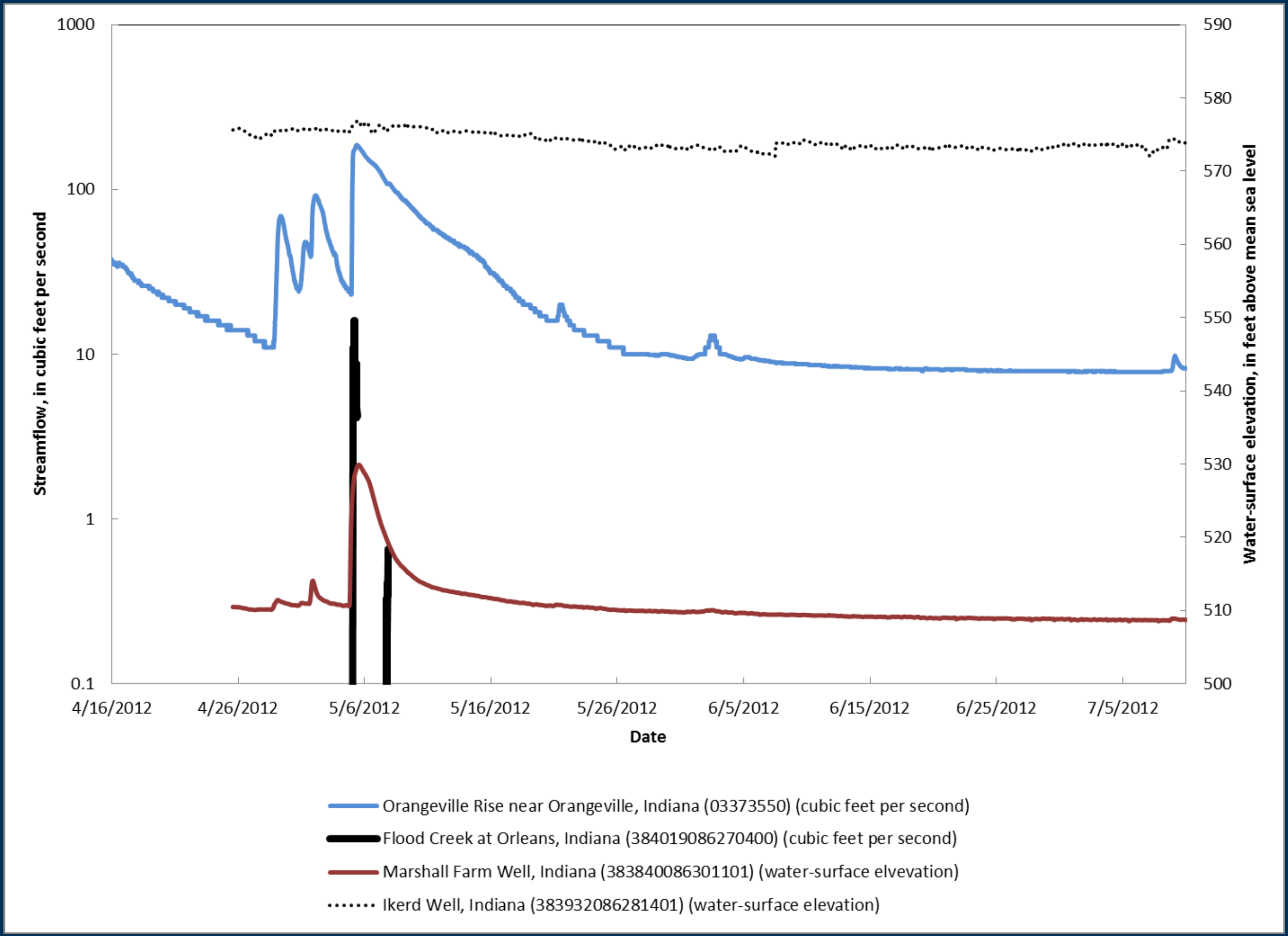
Counter clockwise rotation (hysteresis) shows ground-water levels peaking just after the peak at Orangeville Rise….. Until…

This event (May 5th) shows a "figure-8" pattern between ground-water levels and flow from the Orangeville Rise…



Early clockwise rotation (hysteresis) shows ground-water levels rising rapidly before the peak at Orangeville Rise for this event….. This happens to correspond to an observed peak at the Flood Creek station. Local GW levels should generally track streamflow due to recharge, etc.. (and they do) – but this event (very fast) is indicative of direct communication with a conduit (possibly tied to Flood Creek).

Yet more evidence… Orangeville Rise, GW wells, & Flood Creek Discharge Hydrographs



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GW observation wells installed in April, 2012

So what does this mean?

Lets go back to the streamflow data…

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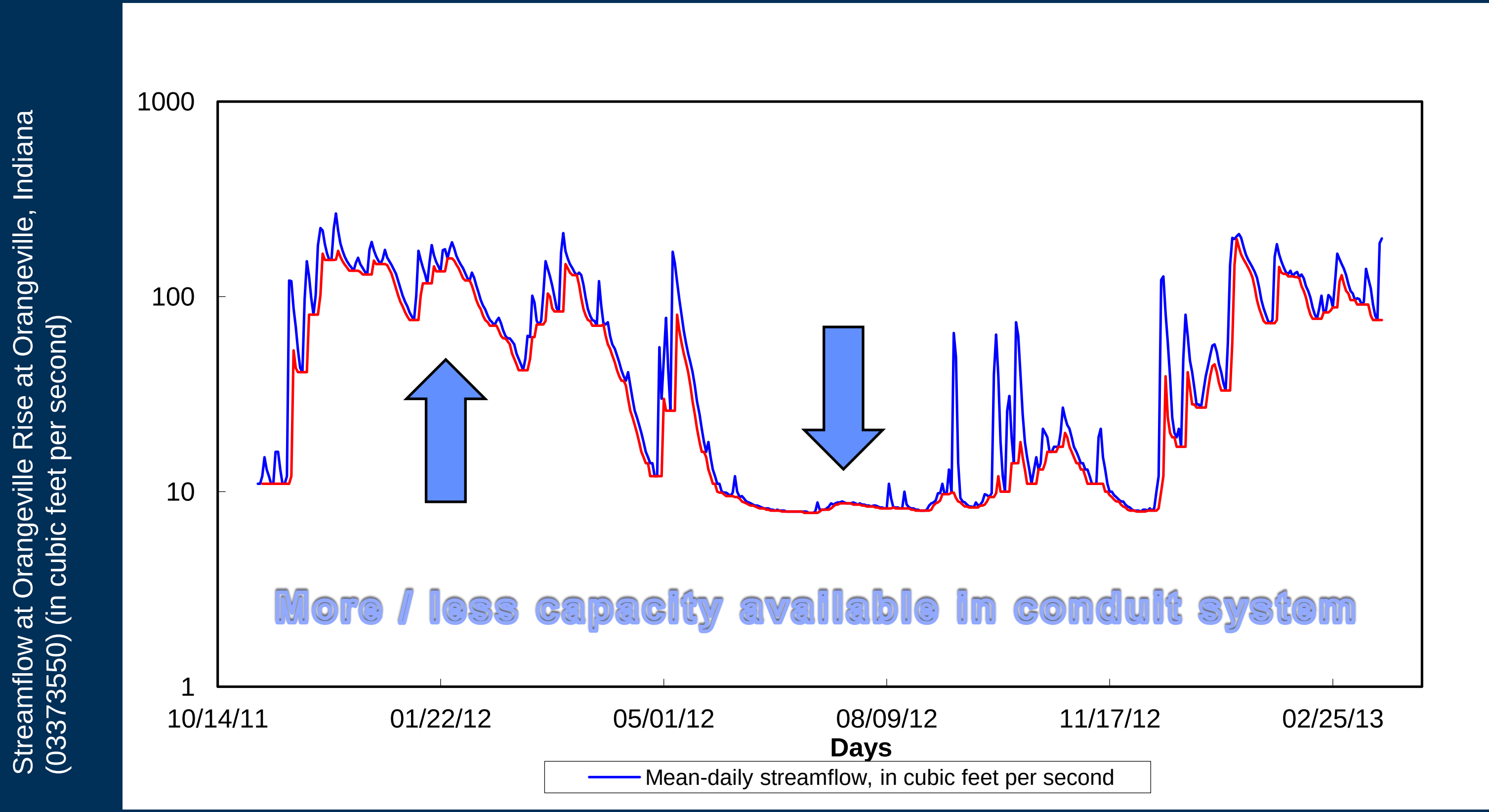
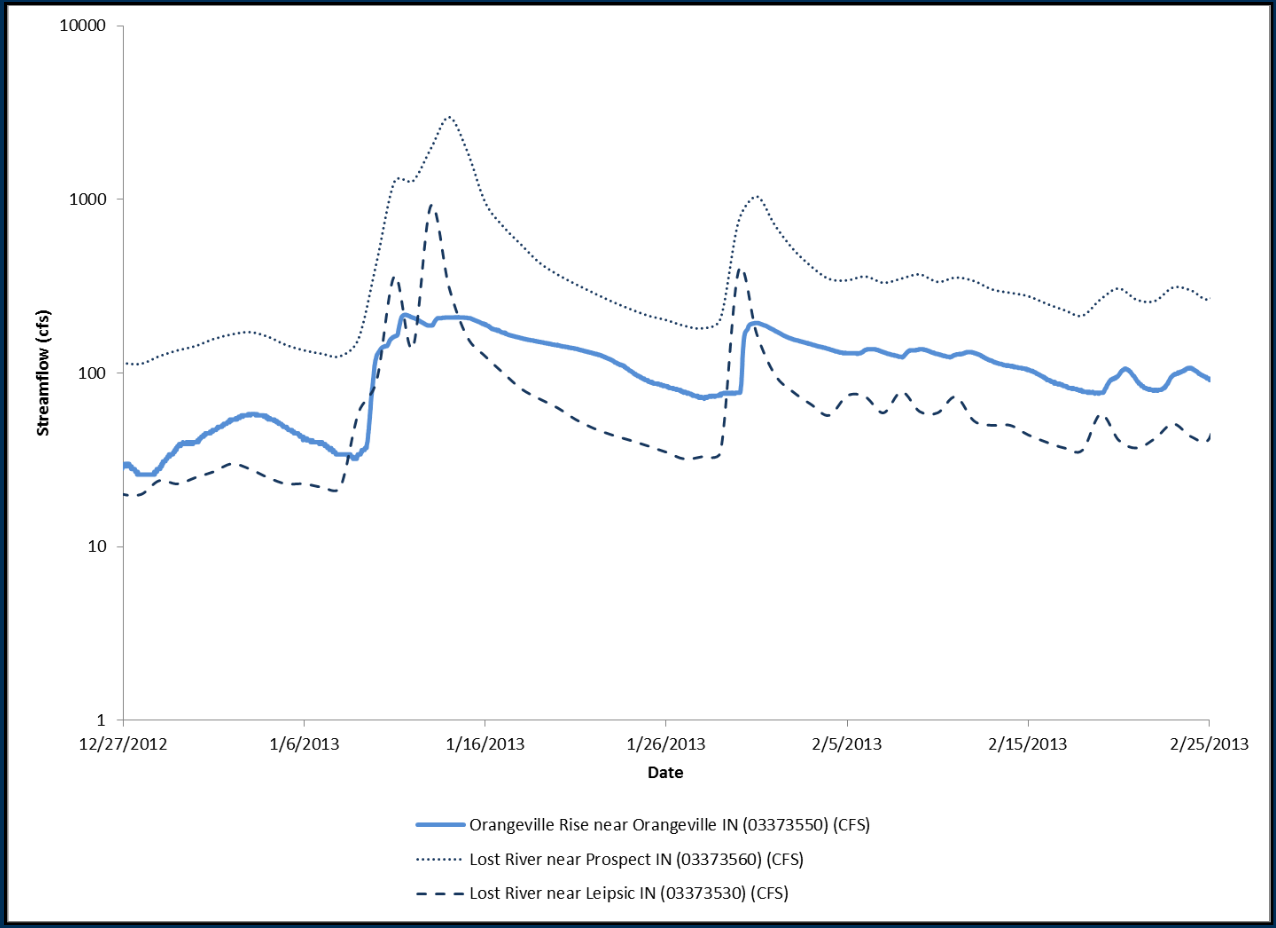
Hydrograph separation – the "base"



This plot helps to show "how full" the system has become and usually correlates to soil and ground-water in non-karst areas – here, it's more indicative of the capacity of the conduit system. Plot appears to define a bounding condition (around 200CFS) – again, based on LIMITED data. Related stormwater rises serve as "pop-off valves" in relation to potential hydraulic-damming in the OV Rise conduit itself.

USGS

Hydrograph separation – the "base"



Note the Orangeville Rise recession as compared to the Lost River hydrographs

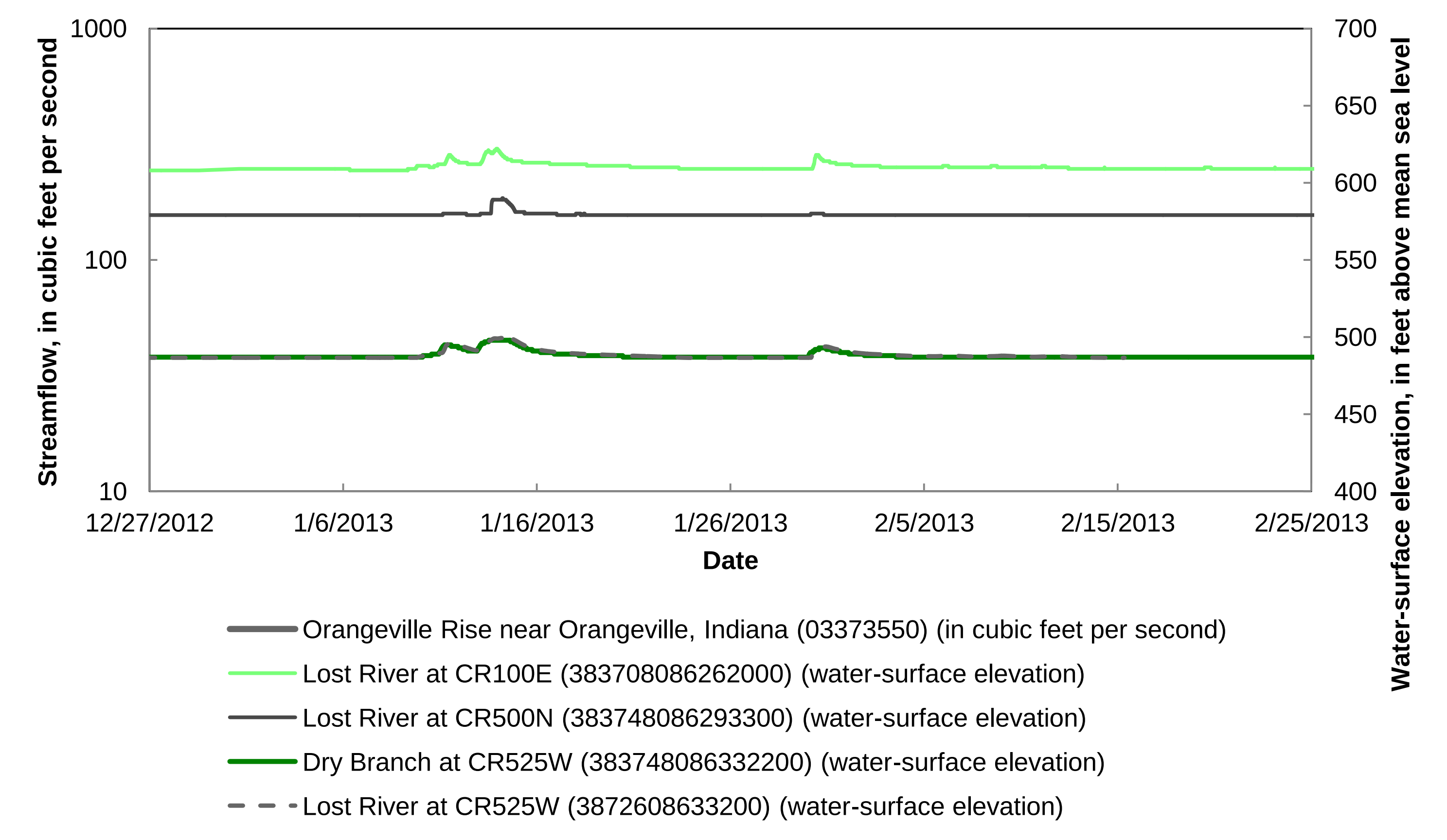
Karst resurgences along downstream Lost River flow when the conduit system is full.

Orangeville Rise resurgences

<u>Mather's stormwater rise</u> — primary overflow spring for Orangeville Rise karst basin: (top, at base or low flow; left, at high flow).

USGS

Orangeville Rise and partial-record stations in the region.



Surface flows (during this time) appear more likely to happen when the system's "base" is higher and additional contributions (Flood Creek) likely cause the storage / capacity of the conduit system to be exceeded. Local inputs from Dry Branch and others can add to the issue as well (depends on where it rains, how hard is rains, etc..).

So what does all this point to?

- Again, these interpretations will likely be refined with additional data; this is a starting point.
- When the Orangeville Rise system is “tanked up”, it shows up in the sentinel-gage data; when this condition exists, surface flows appear to be more likely during subsequent events.
- Flood Creek contributions in the headwaters appear to stress the local conduit system. If Flood Creek inputs occur along with a “tanked up” OV Rise, surface flooding could be a greater possibility (especially in the local Orleans area).

USGS

So what does all this point to?

- Downstream flooding of Lost River (the perennial reach below Orangeville) is dependent on the discharge from OV Rise, its stormwater overflow springs , the contribution of the true Rise of Lost River itself, and then the input from Lick Creek. All of this contributes to flooding at French Lick/West Baden.

- The swallow hole or cave opening that normally drains Flood Creek to the underground is typically choked up with sediment and debris; this also contributes to localized flooding at Orleans.

- A bit of warning - localized storm events can always still form over specific parts of the basin and drive independent flooding events (Dry Branch and so forth).

Let us then look at a model and its uses.

Model results coupled with data from the field (sentinel gages) can allow you to plan, predict, refine, and protect within some level of statistical certainty (models are <u>not</u> perfect – especially in karst).

<u>Some questions we might answer with a model:</u>

Are flows into Flood Creek going to increase if we alter the land use / cover?

What if the climate changes in the future – will it get better or worse?

Etc..

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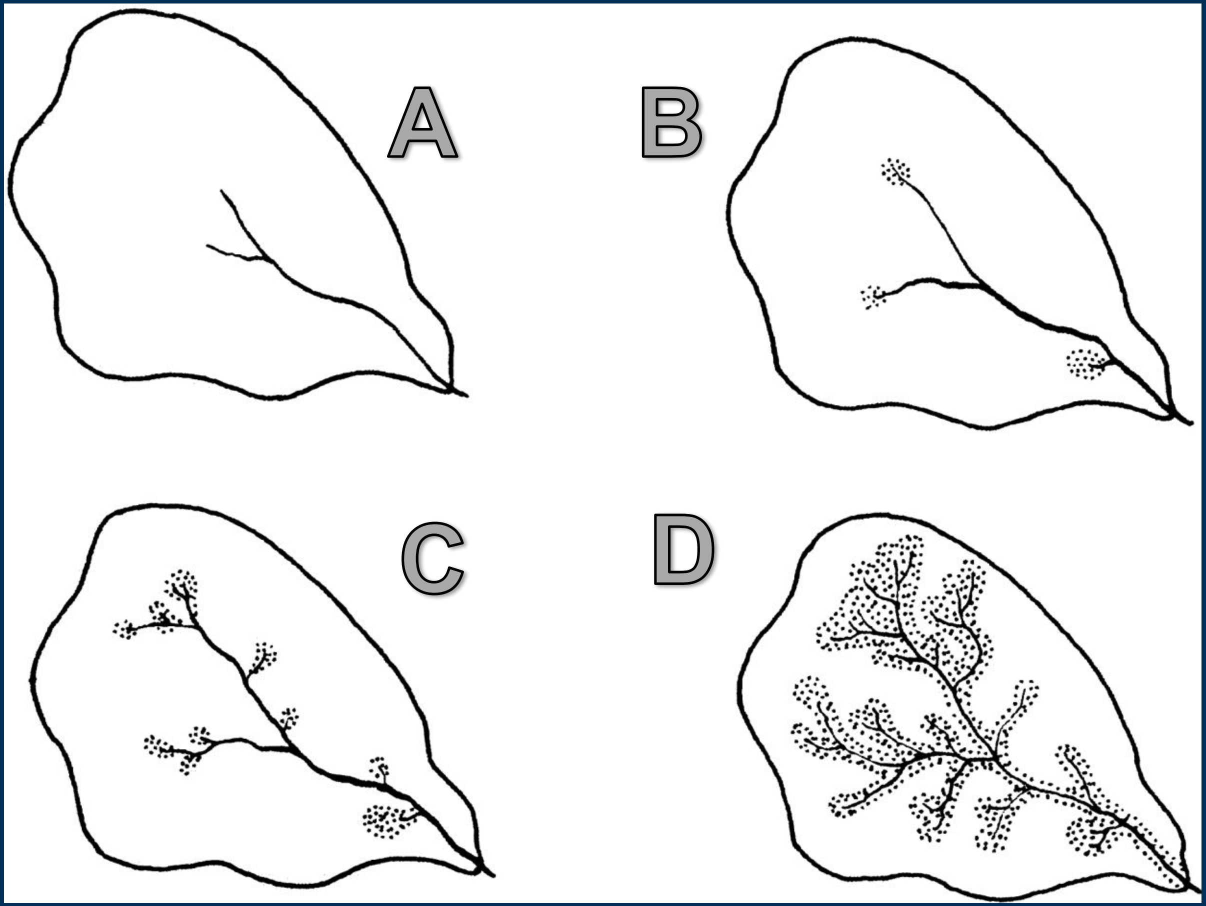
TOPMODEL – Topographically-based hydrological model that simulates the variable source-area concept of streamflow generation



Figures A-D show evolution of saturated areas during a precipitation event.

Given this, we quantify how water accumulates on the landscape, soil properties, precipitation intensity, and more to quantify water at the basin outlet.

In internally-drained areas, water bypasses the unsaturated zone moves to the outlet directly (SDP process - Taylor and others, 2011).

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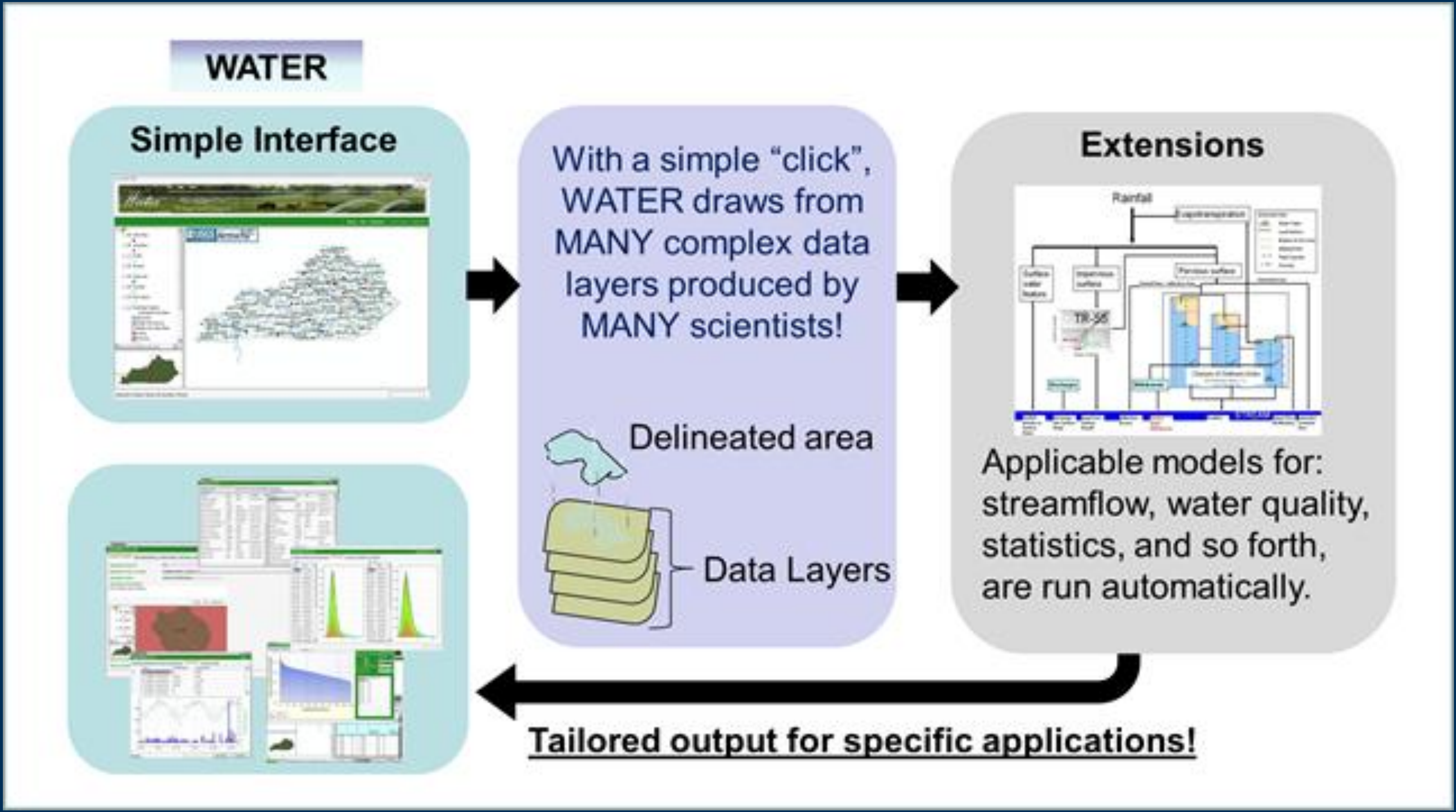
TOPMODEL - Beven, K.J. and M.J. Kirkby. 1979.
Figure is somewhat ubiquitous and was modified from unknown author

WATER Version 2 –
Water Availability Tool for Environmental Resources



WATER-TOPMODEL

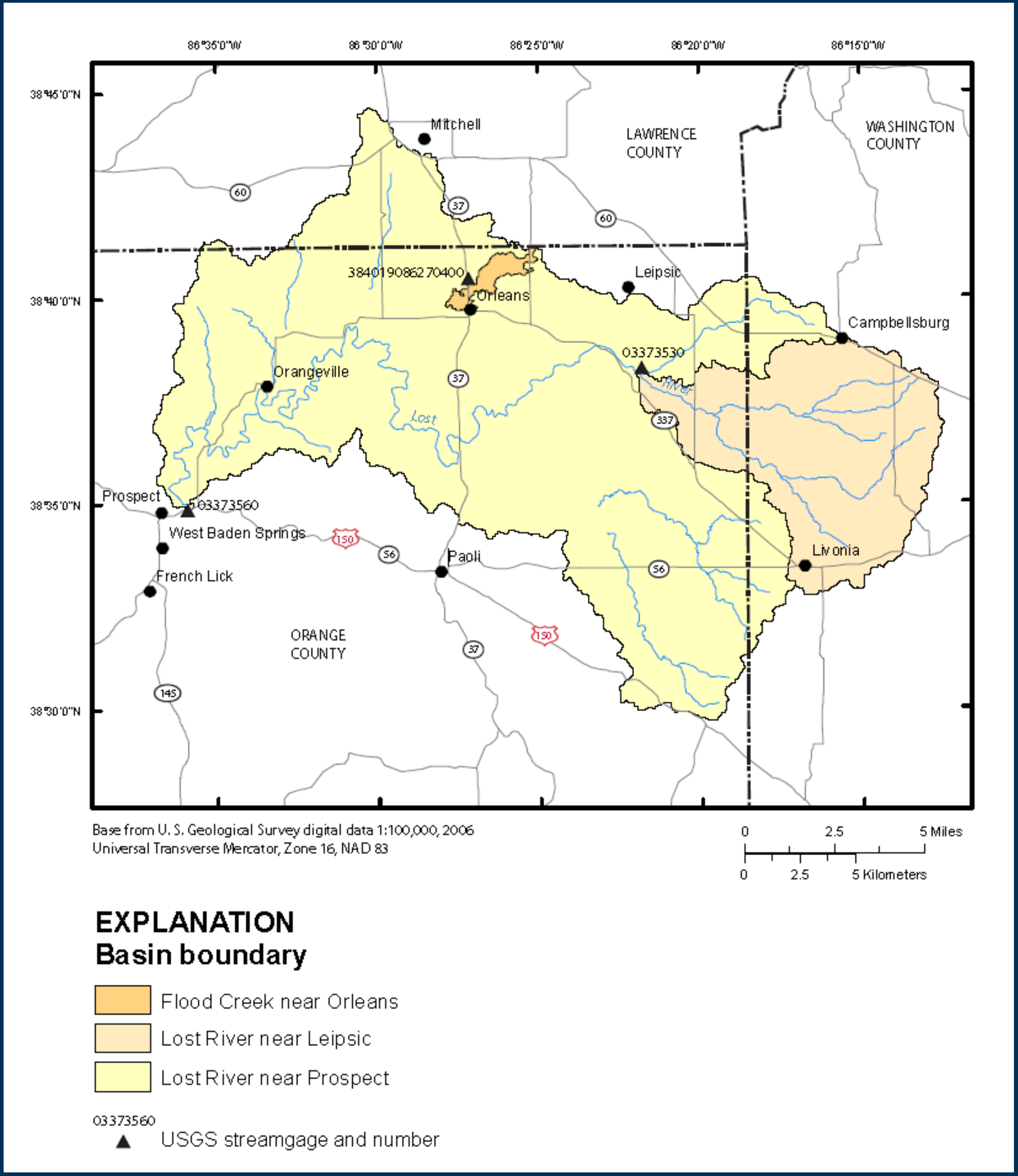
WATER v2 used unmodified “SDP” code developed by Taylor and others (2011)

3 basins modeled

Lost River @ Prospect, IN

Lost River @ Leipsic, IN

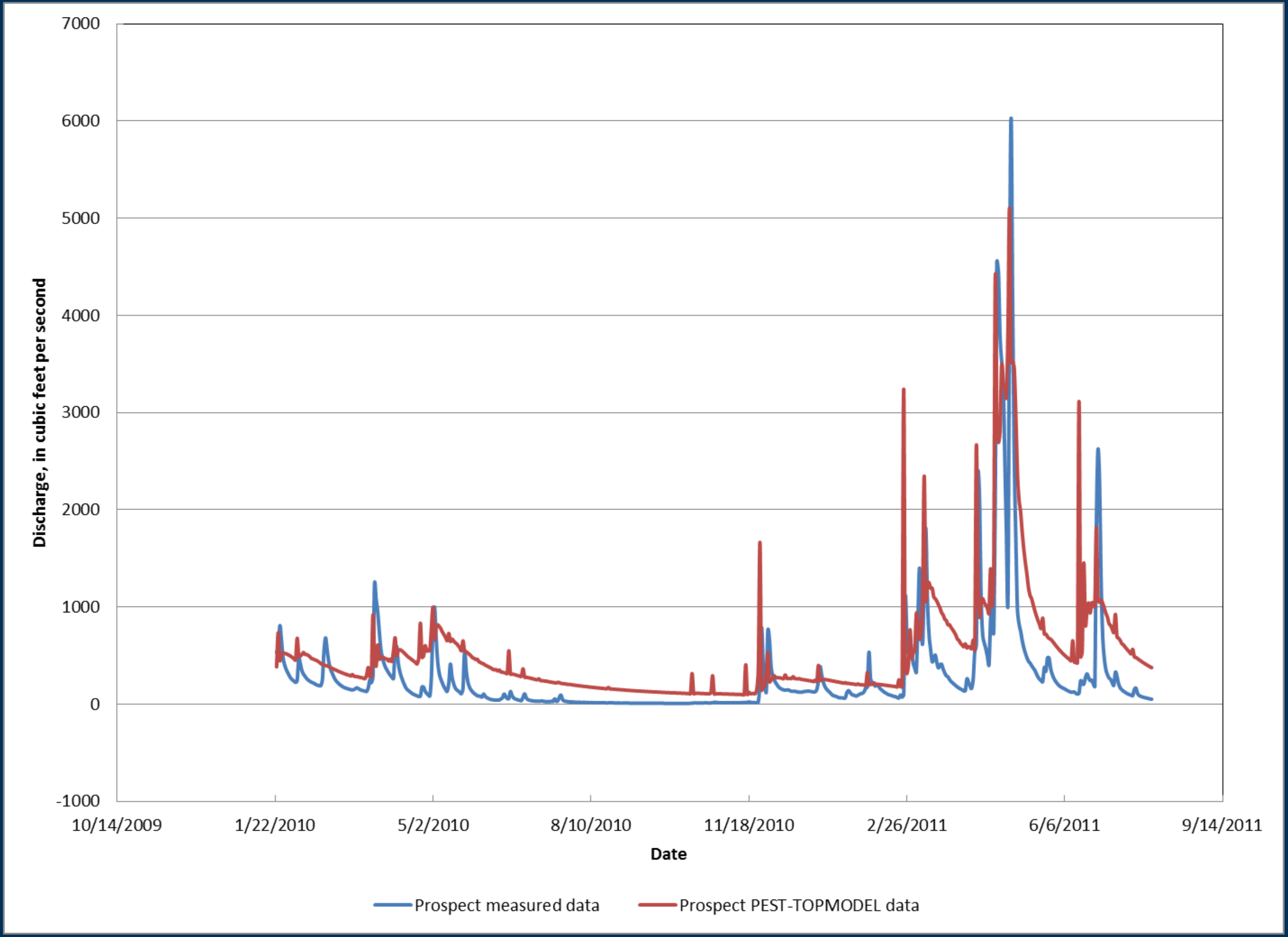
Flood Creek @ Orleans, IN



Validation data from a topographically-based hydrologic model (TOPMODEL)

NSE = 0.39

Correlation Co. = 0.60

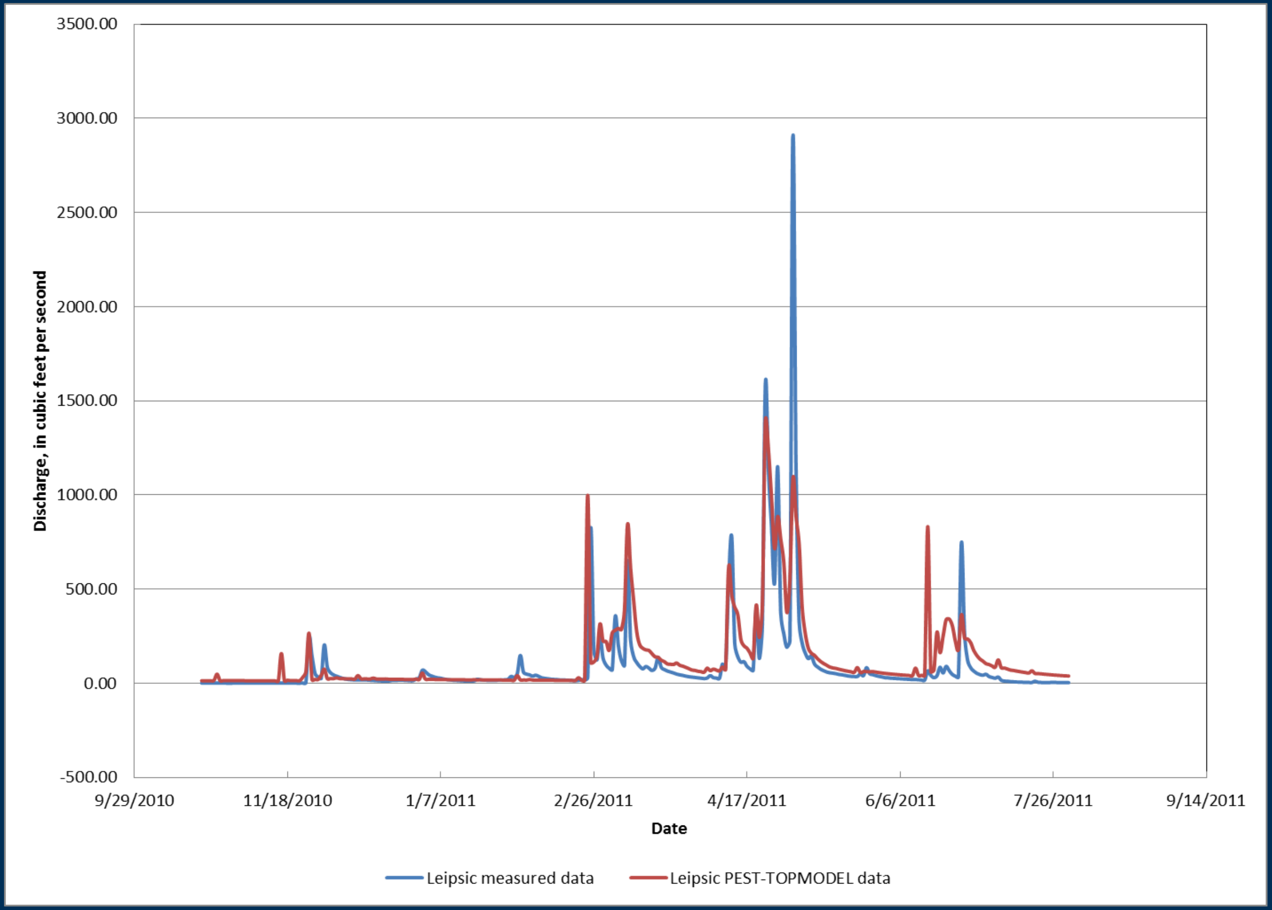


This model was built for the Lost River region and provides an approximation of flows in that given reach. Lost River at Prospect gage (USGS 03373560)

Validation data from a topographically-based hydrologic model (TOPMODEL)

NSE = 0.56

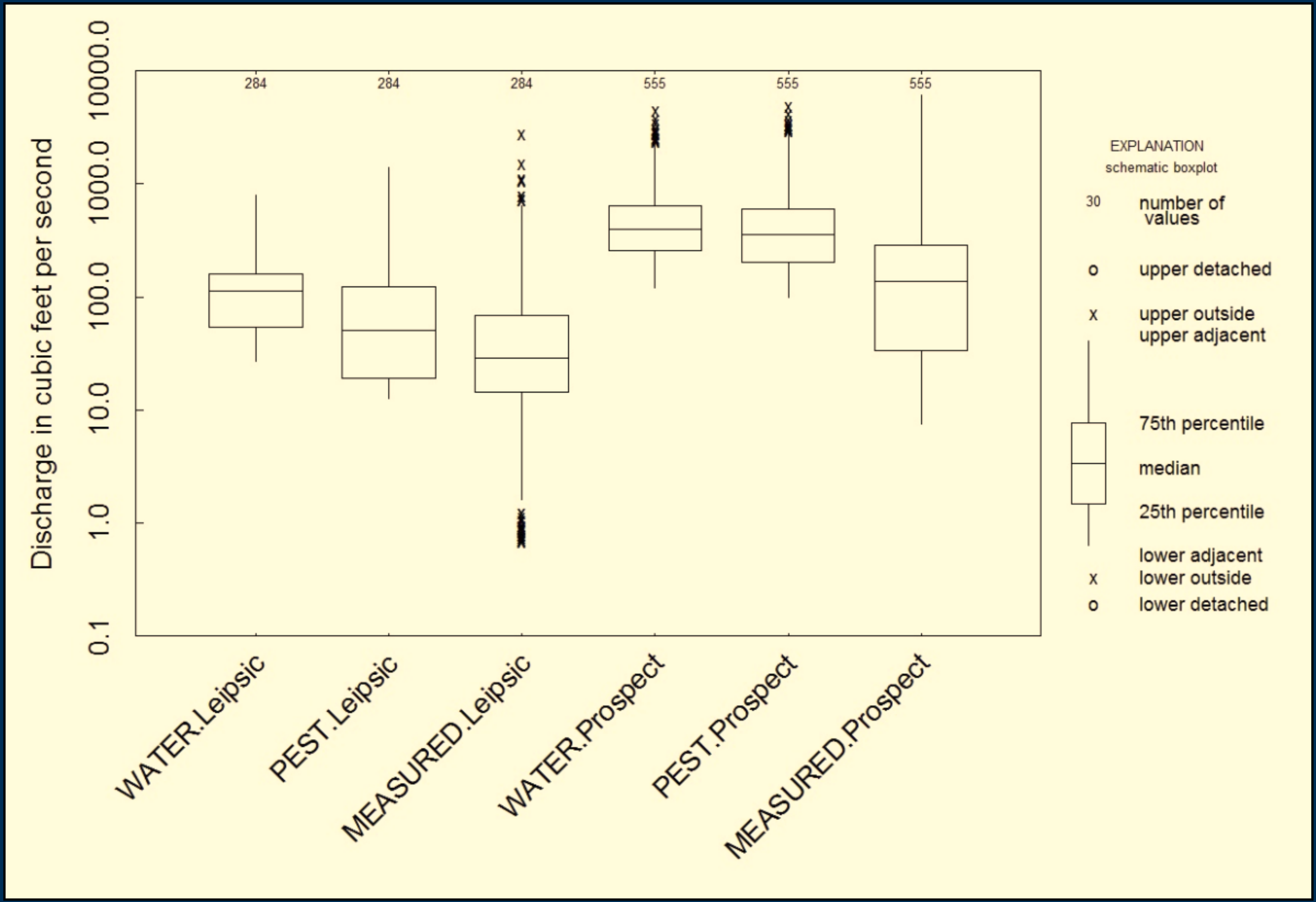
Correlation Co. = 0.58



USGS

This model was built for the Lost River region and provides an approximation of flows in that given reach. Lost River at Leipsic gage (USGS 03373530)

TOPMODEL validation



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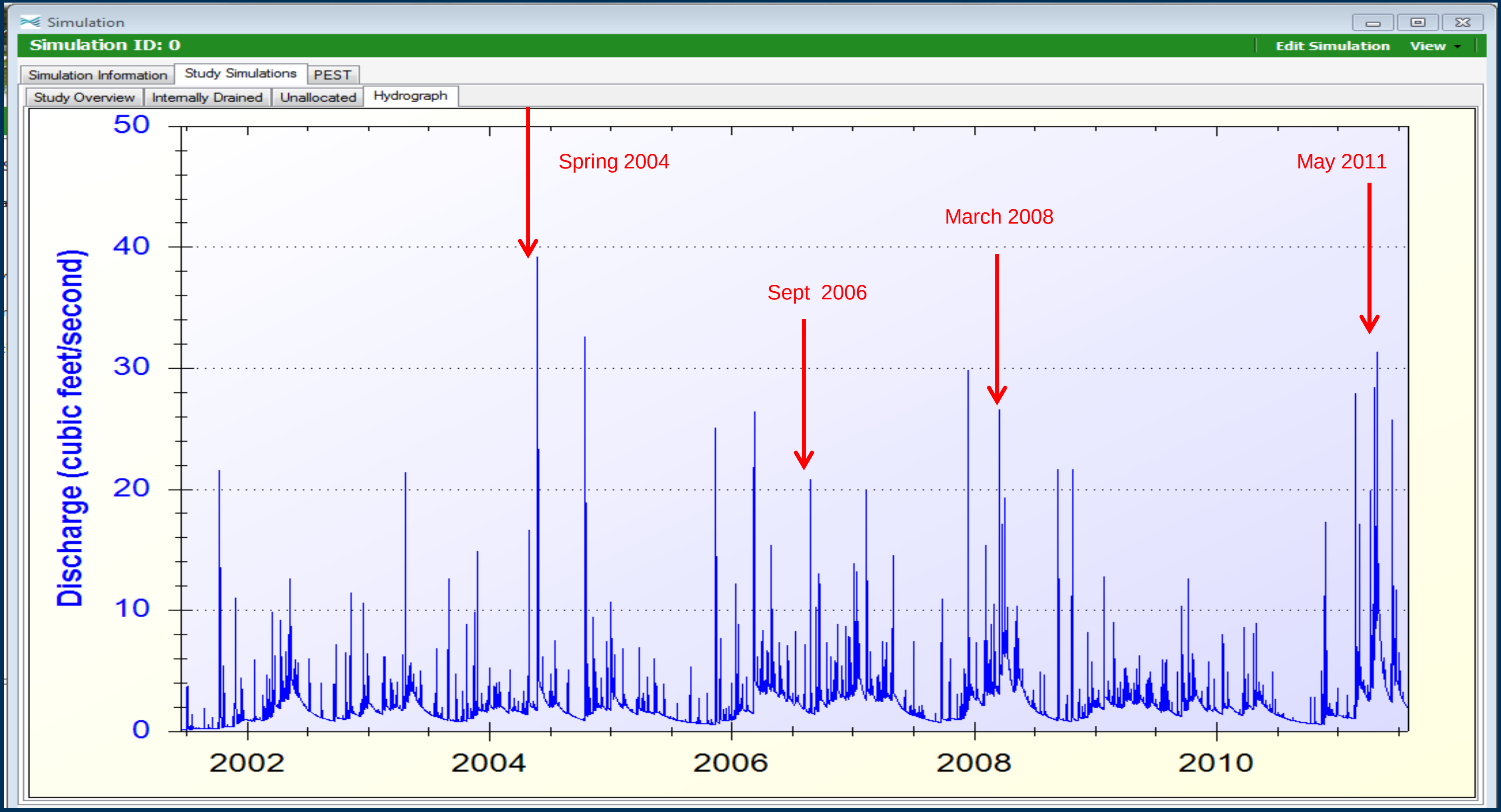
How do these model estimates fit with the gage data?

TOPMODEL output for Flood Creek

(assume we're doing at least as good as where we could test it against gage data).



Where to next?

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Need to evaluate where the sentinel stations need to be to provide flood-warning and improved understanding. They're important, provide critical data, and fix models to reality.

Need to refine and improve the model / GUI. Models improve with understanding of the region / needs – so they tend to get better with time.

We know more now and can improve the SDP process with better representation of conduits and epikarst (better implementation of regional quick- / slow-flow components).

This science leads to better engineered solutions.

We are already working on improving the science!

WATERπ being developed from this model. WATERπ will be used for new tools:

Columbus, IN flood-inundation project

and

Cumberland Gap National Park.


Questions?
USGS